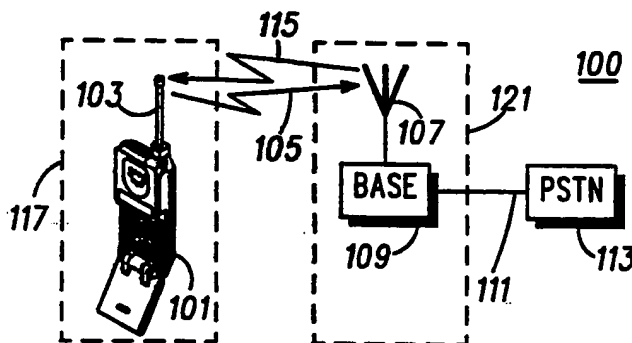


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(54) Title: WIRELESS PERSONAL COMMUNICATION SYSTEM



(57) Abstract

A wireless personal communication system (100) comprising a transmitter and a receiver (117) arranged to communicate via a radio frequency link (105, 115) is provided. The transmitter (117) breaks a message to be sent into segments, and then encodes the segments into a like number of individual packets, the k th packet containing two segments, namely, a version of the present or k th segment and a version of the preceding or $(k-1)$ th segment. Thus, each message segment is sent twice, in adjacent packets. Each packet is then transmitted on the radio link (105, 115), the sequence of packets being received by the receiver (117). The receiver (117) then decodes each packet into its two message segment components. Thus, the k th received packet contains two segments, namely, a version of the k th segment and a version of the $(k-1)$ th segment. Thus, each individual message segment is received two times, the first occurrence resulting in a first version, and the second occurrence resulting in a second version, in adjacent packets. After receiving the second version of any given message segment, the receiver (117) selects the version of that segment that is the highest quality, or lowest error. The higher-quality version thus selected is saved and used for message reconstruction, whereas the other lower-quality version is discarded. As a result of this process, the receiver can faithfully reproduce the original message. In the preferred embodiment, the frequency for each packet to be sent (or received) changes according to an algorithm or pattern specially determined to minimize the probability that any two packets immediately adjacent to one another might be degraded.

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WIRELESS PERSONAL COMMUNICATION SYSTEM

Technical Field

This application relates to a wireless personal communication
5 system.

Background of the Invention

There is an emerging world market need for local area wireless
personal communications. In many parts of the world government
10 agencies have allocated frequency spectrum for this type of service. In
the United States, the FCC has stated that there is no spectrum that can
be granted to this service on a license primary user basis. It has,
however, stated that three Industrial, Scientific and Medical (ISM) bands
may be used for this purpose on a shared secondary basis provided low-
15 power spread-spectrum transmissions are used. Recently, the FCC
issued specific rules pertaining to this type of service.

It is apparent that if one can provide a system compliant with these
rules at a low cost that is resilient to the interference that might be
encountered while operating in the ISM band on a secondary basis, it
20 would service a growing need for local area communications.

Summary of the Invention

Accordingly, a wireless personal communication system is
provided that is particularly suited for virtual real-time voice in either one-
25 way or two-way operation. The term "virtual real time" in voice
communications is meant

to imply that the delays in the communications channel are short enough so as to be unobjectionable to the user. In duplex communications, one way delays of less than 1/4 second with echo cancelling are generally considered to meet this criteria.

5 The wireless personal communication system, according to the invention, comprises a transmitter and a receiver arranged to communicate via a radio frequency link. The transmitter breaks a message to be sent into segments 0, 1, 2, . . . , k-1, k, k+1, . . . and so forth. The transmitter then encodes the message segments into a like
10 number of individual packets, the kth transmitted packet containing two segments, namely, a version of the present or kth segment and a version of the preceding or (k-1)th segment. Thus, each individual message segment is sent two times, in adjacent packets. Each packet is then transmitted on the radio link. In the preferred embodiment, the frequency
15 of the radio link is changed for each packet to be sent.

 The receiver thus receives a sequence of packets on the radio link. In the preferred embodiment, the receiver changes frequency for each packet to be received. The receiver then decodes each packet into its two (2) message segment components. Thus, the kth received packet
20 contains two segments, namely, a version of the present or kth segment and a version of the preceding or (k-1)th segment. Thus, each individual message segment is received two times, the first occurrence resulting in a first version, and the second occurrence resulting in a second version, in adjacent packets. After receiving the second version of any given
25 message segment, the receiver selects the version of that segment that is the highest quality, or lowest error. The higher-quality version thus

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selected is saved and used for message reconstruction, whereas the other lower-quality version is discarded. As a result of this process, the receiver can faithfully reproduce the original

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message comprising message segments 0, 1, 2, . . . , k-1, k, k+1, . . . and so forth.

In the preferred embodiment, the frequency for each packet to be sent (or received) changes for each packet according to an algorithm or
5 "hopping" pattern specially determined to minimize the probability that any two packets immediately adjacent to one another might be degraded.

Brief Description of the Drawings

10 Fig. 1 is a block diagram that shows a first embodiment of a wireless personal communication system, according to the invention.

Fig. 2 is a time-domain diagram showing various frequency hop formats for the first embodiment.

15 Fig. 3 is a time-domain diagram showing a typical frequency hop cycle for the first embodiment.

Fig. 4 is a block diagram of a typical telephone transceiver 117 for the first embodiment.

Fig. 5 is a block diagram showing the transmit path 501 for the transceiver 117 of Fig. 1 and the receive path 503 for the base station
20 121 of Fig. 1.

Fig. 6 is a truth table showing the preferred implementation of the coding technique for the first embodiment.

Fig. 7 is a time-domain diagram showing various stages of message processing for the typical transceiver 117 and base unit 121 of
25 the first embodiment.

Fig. 8 is a truth table to accompany Fig. 7.

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Fig. 9 is a frequency-domain diagram showing a typical frequency hop cycle for the first embodiment.

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Detailed Description of the Invention

Referring now to Fig. 1, there is shown a first embodiment 100 of a wireless personal communication system, according to the invention.

There is shown a telephone handset 101 integrally equipped with

5 transceiver means 103. As is known, a transceiver is a 2-way communications device containing both a transmitter and a receiver. It will be apparent that the assembly of the telephone handset 101 and integral transceiver means 103 may be collectively referred to as the telephone transceiver 117.

10 The telephone transceiver means 103 is coupled to a base unit transceiver means 107 by means of a first RF communication link 105 designated as "primary" and a second RF communication link 115 designated as "redundant". The base unit transceiver unit 109 contains further power and control functions, and is linked to a public switching
15 telephone network ("PSTN") 113 by means of channel 111. It will be apparent that the assembly of the base unit 109 and transceiver means 107 may be collectively referred to as the base unit 121.

As will become apparent, one use of the wireless personal communication system 100, according to the invention, is that it may be
20 used to support a telephone call. For instance, a user can use the telephone transceiver 117 to communicate with the base unit 121 via the RF communications links or virtual channels 105 and 115, and thereby cause the base unit 121 to initiate an outgoing PSTN telephone call via the channel 111. In the alternative, a remote PSTN user (not shown) can
25 use the PSTN 113 to complete an incoming PSTN telephone call the local user of telephone transceiver 117 via the base unit 121 and the

channels 105 and 115. The term virtual channel as used herein is derived from the common usage in time division multiple access or "TDMA" formats where each time slot in a TDMA format is referred to as a virtual channel, or a pair as a duplex virtual channel. In a frequency hop
5 application each

communications link using the same hop sequence but at different phases in the sequence can be thought of as occupying different virtual channels in the sequence.

Fig. 2 is a time-domain diagram showing various frequency hop
5 formats for the first embodiment.

Referring now to Fig. 2, thus it is seen that, if there are 6 frequencies in the sequence, as illustrated in W of Fig. 2, and the time slot duration at every frequency is further divided into 4 time slots as in TDMA, there are a total of 24 virtual channels, one of which is illustrated
10 in X of Fig. 2. The virtual channels may be paired for duplex communications as illustrated in Y and Z, both of Fig. 2.

Referring now to X of Fig. 2, it will be appreciated that virtual channels occupying the A or B time slots of each hop period contain information flowing from the handset element 117 to the base unit 121
15 and the virtual channels occupying the C or D time slots of each hop period contain information flowing from the base unit 121 to the handset unit 117. Further insight is available from Fig. 2.

Referring now to Y of Fig. 2, a pair of virtual channels, for instance occupying the A and C time slots on the same frequency may be
20 considered a duplex virtual channel such as 105 on Fig. 1. Likewise a pair of virtual channels occupying the B and D time slots on the same frequency may be considered another duplex virtual channel such as 115 on Fig. 1.

One important difference between the system of Fig. 1 and prior art
25 wireless telephone arrangements is, for example, the use of two RF

virtual channels 105 and 115, instead of the usual single virtual channel arrangement. Still further distinctions will become apparent.

As for the use of two virtual channels 105 and 115, the applicant has discovered that, by causing the frequency assignments for each time

5 frame

to vary with time, also known as "frequency hopping", the system is able to operate at comparably lower power levels.

Fig. 3 is a time-domain diagram showing a typical frequency hop cycle for the first embodiment.

5 Fig. 4 is a block diagram of a typical telephone transceiver 117 for the first embodiment.

Fig. 5 is a block diagram showing the transmit path 501 for the transceiver 117 of Fig. 1 and the receive path 503 for the base station 121 of Fig. 1.

10 As illustrated in Figs. 4-5, the input voice is digitized and segmented into message blocks using prior art techniques. Each block is then stored in a memory device for later transmission. In order to meet the FCC rules for frequency hop spread spectrum operation, the transmitter transmits a burst on one frequency, and then another, and so
15 on in a frequency hop pattern. Each block of voice is transmitted on at least two different RF channels or frequencies. This is accomplished by time compressing the stored voice block during transmission. In a typical application, a voice block would first be sent as the second half of a first transmission on frequency j , and then again as the first half of the next
20 burst transmission which occurs on the next frequency in the frequency hop pattern, $j+1$. Each transmission, of course, would also contain additional information that would enable the frequency hop receiver to determine which copy of each voice block was most correct in the event both copies were not received error free.

25 Fig. 6 is a truth table showing the preferred implementation of the coding technique for the first embodiment.

Referring now to Fig. 6, it will be appreciated that the parity code is effective in determining if either the copy of the voice segment was received error free. If one copy is error free, then that copy is used as the output.

Further, if both copies have one or more parity errors, then it is concluded that each copy of the voice segment has one or more errors, the number of errors may not be high enough to render the total copy useless. A second criteria of choice between the copies is then utilized.

- 5 The synchronization word ID is provided with each hop transmission to assure continuous synchronization after temporary loss of signal. If, however, the synchronization word associated with a particular copy of a voice segment is received error free, then that is strong evidence that the channel was not seriously corrupted during transmission of the copy in
10 question. Therefore, that copy is used as the output.

Further, if the parity codes associated with each copy have errors and the synchronization word associated with each copy has more than a given number of errors (perhaps even just one), then a default condition is invoked. That condition is to mute the audio during that
15 portion of the voice message. Enhancements are possible. For instance, the parity or error corrective code may be sufficiently reliable so as to support distinction between the two received versions of a voice segment, even if neither is totally error free.

Fig. 7 is a time-domain diagram showing various stages of
20 message processing for the typical transceiver 117 and base unit 121 of the first embodiment.

Fig. 8 is a truth table to accompany Fig. 7.

Referring now to Fig. 7 and Fig. 8, it will be assumed that the
25 transceiver 117 wishes to send a message to the base station 121 in Fig. 1. It will be helpful if the reader also refers to the transmit path 501 of

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transceiver 117, and the receive path 503 of the base station 121, as shown in Fig. 5.

Referring now to Fig. 5, the message to be sent is generated by transmitter element 505. The signal is then digitized by analog to digital converter 507, and input to buffer memory 509. The buffer memory 509 then divides the message into message segments A0, A1, . . . , A11, shown collectively as element 710 in Fig. 7. The segments 710 are then input to combiner 515. The combiner 515 then codes the segments A0, A1 into a packet 731 for transmission to base station 121 via RF link 521 at frequency f1. Synchronization and error detect codes are provided by elements 511 and 513, respectively.

10 The combiner 515 then codes the segments A1 and A2 into packet 733 for transmission to base station 121 via frequency f2.

 The combiner 515 then codes the segments A2 and A3 into packet 735 for transmission to base station 121 via frequency f3.

 The combiner 515 then codes the segments A3 and A4 into packet 15 737 for transmission to base station 121 via frequency f4.

 The combiner 515 then codes the segments A4 and A5 into packet 739 for transmission to base station 121 via frequency f5.

 The combiner 515 then codes the segments A5 and A6 into packet 741 for transmission to base station 121 via frequency f6.

20 The combiner 515 then codes the segments A6 and A7 into packet 743 for transmission to base station 121 via frequency f7.

 The combiner 515 then codes the segments A7 and A8 into packet 745 for transmission to base station 121 via frequency f8.

 The combiner 515 then codes the segments A8 and A9 into packet 25 747 for transmission to base station 121 via frequency f9.

The combiner 515 then codes the segments A9 and A10 into packet 749 for transmission to base station 121 via frequency f10

The combiner 515 then codes the segments A10 and A11 into packet 751 for transmission to base station 121 via frequency f11.

Referring now to Fig. 5, the packets to be received at the base station 121 are received by antenna 523 and receiver 525. The received packets are then input to buffer memory 527, while synchronization is detected by detector 529, and error detection is detected by error
5 detector 531. The packets are then input to controller 533 for message reconstruction. After the message has been reconstructed, it is converted to analog form by digital to analog converter (DAC) 535, and applied to the telephone facility 537.

Assuming now that packet 731 is successfully transmitted via f1
10 and received at the base station 121, the controller will form a received packet 761 comprising message segment A0 and A1. Since this is the beginning of the receive message sequence, the controller 535 is forced to use segment A0 even if it is degraded, and thus sends the segment A0 downstream to DAC 535, telephone link 537, and a remote listener (not
15 shown). The controller then saves the first version of segment A1.

The controller next receives packet 763 via f2, corresponding to transmitted packet 733. This packet contains message segments A1 and A2. The controller now has available to it a first version of A1, from packet 761 and f1, and a second version of A1, from packet 763 and f2.
20 The controller can now select the best version to use based, for instance, on a measure of received signal quality provided by the error detector circuit 531. It will be assumed that the first version is chosen, corresponding to packet 761 and f1, and this version of A1 is thereupon sent downstream to DAC 535. The controller then saves the first version
25 of segment A2.

The controller next receives packet 765 via f3, corresponding to transmitted packet 735. This packet should contain a second version of segment A2, and a first version of segment A3. Due to interference or other transmission problems, however, the packet 765 is degraded to the

5 extent

that it is not usable. As a result, the controller 533, after it receives the distorted version of packet 765, determines that it only has available the first version of segment A2 from packet 763. Thus, it now sends this version of segment A2 downstream to DAC 535.

5 The controller next receives packet 767 via f4, corresponding to transmitted packet 737. This packet contains the second version of segment A3 and a first version of segment A4. Since packet 765 was degraded, however, then controller 533 has available only one version of segment A3, namely, the second version in packet 767. Thus, the
10 controller now sends this version of segment A3 downstream to DAC 535. The controller then saves the first version of segment A4.

 The controller next receives packet 769 via f5, corresponding to transmitted packet 739. This packet contains the second version of A4 and the first version of A5. Since the controller 533 now has available to
15 it two versions of segment A4, namely the first version from packet 767, and the second version from packet 769, the controller now decides which segment to use. This decision may be made by measuring the quality of the two versions, and using the highest quality (lowest error) version. Or, if the two versions are roughly equal in quality, the controller
20 may use either version. In any event, at this point the controller 533 selects a version of segment A4 to use, and sends it downstream to DAC 535. The controller then saves the first version of segment A5.

 This process thus proceeds with subsequent received packets 771, 773, 775, 777, 779, and 781, corresponding to transmitted packets
25 741, 743, 745, 747, 749, and 751, via f6, f7, f8, f9, f10, and f11. As each new packet is received, the process described above is repeated.

As a result, upon receipt of packet 771, the controller selects the best version of A5, and sends it downstream to DAC 535.

Note that packet 773 is degraded to the extent that the second version of segment A6 and the first version of segment A7 are lost. In this case, the controller sends the first version of A6 downstream.

5 Upon receipt of packet 775, the controller sends the second version of A7 downstream.

Upon receipt of packet 777, the controller selects the best version of A8, and sends it downstream.

Upon receipt of packet 779, the controller selects the best version of A9, and sends it downstream.

10 Upon receipt of packet 781, the controller selects the best version of A10, and sends it downstream.

Ultimately, the DAC 535 is able to reconstruct the entire message A0, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, . . . , which message it transmits downstream to the telephone facility 537 to a remote listener
15 (not shown).

It will be appreciated that successful utilization of the ISM band or other bands for spread spectrum radio transmission must consider the implication that a portion of the band may not be usable either
20 permanently or for short periods of time because of either multipath fades or interference. While long term impairments may be circumvented by avoiding the segment of the band in question, impairments of short duration must be addressed by the modulation, filtering or error correction coding techniques employed. An essential element of the
25 invention is that each portion of the voice signal is transmitted at least twice on at least two different frequencies. Another key is that sequential

frequencies in the hop sequence represent a frequency change greater than the bandwidth of the anticipated impairments.

Fig. 9 is a frequency-domain diagram showing a typical frequency hop cycle for the first embodiment.

In the preferred embodiment, the frequency for each packet to be sent (or received) changes for each packet according to an algorithm or "hopping" pattern specially determined to minimize the probability that any two packets immediately adjacent to one another might be degraded.

The hop sequence represented by Fig. 9 has a frequency change of approximately 1/2 the bandwidth of the ISM band each hop. This hop sequence is effective in avoiding the interference of a single wideband impairment but is vulnerable to multiple impairments separated by 1/2 the total bandwidth of the spread spectrum transmission. The following sequence was generated by a pseudo-random number generator with a gating rule that each hop must represent at least a minimum change in frequency, in this case approximately 1/3 of the total band. The following is the sequence:

15

48, 6, 36, 80, 38, 73, 19, 75, 14, 41, 74, 39, 3, 44, 8,

51, 17, 47, 16, 57, 2, 81, 53, 24, 70, 40, 11, 71, 1, 52, 0, 35, 5, 49, 82, 30,
62, 9, 68, 18, 45, 10, 61, 28,

67, 27, 63, 25, 56, 21, 79, 22, 60, 4, 59, 32, 69, 34, 72, 33, 77, 46, 7, 66,
26, 54, 12, 65, 23, 55, 13, 42, 76,

31, 58, 29, 64, 37, 78, 43, 15, 50, 20.

Relative to operating in the ISM band, the second sequence is preferred since it meets the FCC rules for pseudo-random sequences and because
5 it is more effective in avoiding multiple impairments that may occur in the ISM band.

Returning now to Fig. 3, it is apparent this figure illustrates the time domain of the preferred embodiment. In this figure the base first transmits a copy of the voice that was transmitted for the first time on the
10 previous transmission. The base then transmits the most recent copy of the outgoing voice signal. The handset then transmits two segments in like fashion. It is clear from this diagram that the format takes the nature of a TDMA system. Since TDMA systems are becoming more popular, and because TDMA systems must cope with multipath fading and in
15 some cases interference, the disclosed invention is especially applicable. In such an application the frequency of the TDMA transmission would be switched from frame to frame in order to provide the diversity that achieves the immunity to interference and multipath fading described above. In the TDMA application, these goals may be
20 achieved by utilizing as few as two frequencies.

While various embodiments of a wireless personal communication system, according to the present invention, have been described hereinabove, the scope of the invention is defined by the following claims.

What is claimed is:

Claims

1. In a radio communications system having a transmitter arranged to
5 transmit to a receiver using any one of a plurality of frequencies ("f") in a
sequence ... $f_{(j-1)}$, f_j , $f_{(j+1)}$... , a method for the transmitter to send a
message to the receiver, the method comprising the steps of:
 - (a) dividing the message into message segments m_1 , m_2 , m_3 , ... ,
10 and so forth;
 - (b) for the kth segment m_k , where $k = 1, 2, 3, \dots$, and so forth:
 - (1) forming a corresponding packet_k based on m_{k-1} and m_k ;
 - (2) determining a frequency f_j ;
 - (3) transmitting the packet_k on the frequency f_j ;
 - 15 (4) repeat (1) through (3) for next j and next k.

2. In a radio communications system having a receiver arranged to receive from a transmitter using any one of a plurality of frequencies ("f") in a sequence ... $f_{(j-1)}$, f_j , $f_{(j+1)}$, ... a method for the receiver to receive a message from the transmitter, the method comprising the steps of:

5

for $k = 1, 2, 3, \dots$, and so forth:

- (a) determining a frequency f_j ;
- (b) receiving a packet_k on the frequency f_j ;
- (c) forming a first version of received message segment m_k based on

10 the received packet_k;

- (d) forming a second version of received message segment m_{k-1} based on the received packet_k;

- (e) determining received message segment m_{k-1} based on the first version of received message segment m_{k-1} and the second version of
- 15 received message segment
- m_{k-1}
- , and the quality or error level of the first version and the second version;

- (f) repeat (a) through (e) for next j and next k ;
- (g) form a received message based on received message segments m_1, m_2, m_3, \dots , and so forth.

3. In a radio communications system having a transmitter arranged to transmit to a receiver using any one of a plurality of frequencies ("f") in a sequence . . . $f_{(j-1)}$, f_j , $f_{(j+1)}$. . . , a method for the transmitter to send a message to the receiver and for the receiver to receive a message from the transmitter, the method comprising the steps of:

at the transmitter:

- (a) dividing the message into message segments m_1 , m_2 , m_3 , . . . , and so forth;
- 10 (b) for the k th segment m_k , where $k = 1, 2, 3, \dots$, and so forth:
- (1) forming a corresponding packet $_k$ based on m_{k-1} and m_k ;
 - (2) determining a frequency f_j ;
 - (3) transmitting the packet $_k$ on the frequency $_j$;
 - (4) repeat (1) through (3) for next j and next k ;

15

at the receiver, for $k = 1, 2, 3, \dots$, and so forth:

- (a) determining a frequency f_j ;
- (b) receiving a packet $_k$ on the frequency f_j ;
- (c) forming a first version of received message segment m_k based on the received packet $_k$;
- 20 (d) forming a second version of received message segment m_{k-1} based on the received packet $_k$;
- (e) determining received message segment m_{k-1} based on the first version of received message segment m_{k-1} and the second version of
- 25 received message segment m_{k-1} , and the quality or error level of the first version and the second version;

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- (f) repeat (a) through (e) for next j and next k ;
- (g) form a received message based on received message segments m_1, m_2, m_3, \dots , and so forth.

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4. In a transmitter arranged for communicating with a receiver via a radio frequency link, a method for transmitting a message comprising the following steps:

(a) dividing the message to be sent into segments 0, 1, 2, . . . ,
5 k-1, k, k+1, . . . , and so forth;

(b) encoding the message segments into a like number of individual packets, the kth transmitted packet containing two segments, that is, a version of the present or kth segment and a version of the preceding or (k-1)th segment, so that each individual message segment
10 is sent two times, in adjacent packets, and,

(c) transmitting each packet on the radio link;

(d) changing the transmit frequency for each packet to be sent.

5. The method of claim 4 wherein said changing step (d) includes a
15 step of determining the new frequency for each packet to be sent according to an algorithm or "hopping" pattern specially determined to minimize the probability that any two packets immediately adjacent to one another might be degraded.

20 6. The method of claim 5 wherein said "hopping" pattern is defined as follows:

(a) define J frequencies in the hopping sequence;

(b) arrange the frequencies in a pseudo-random sequence, . . .
 $f_{(j-1)}, f_j, \dots$, such that $|f_{(j-1)} - f_j| > \Delta f$, where $\Delta f > 5$ MHz.

7. The method of claim 6 wherein the sequence of frequencies, $\dots f_{(j-1)}, f_j, \dots$, is defined as follows:

a set of 83 frequencies identified according to their ascending order, the following list being the order of the sequence:

5 48, 6, 36, 80, 38, 73, 19, 75, 14, 41, 74, 39, 3, 44, 8, 51, 17, 47, 16, 57, 2, 81, 53, 24, 70,

40, 11, 71, 1, 52, 0, 35, 5, 49, 82, 30, 62, 9, 68, 18, 45, 10, 61, 28, 67, 27,
63, 25, 56, 21, 79, 22, 60, 4,

59, 32, 69, 34, 72, 33, 77, 46, 7, 66, 26, 54, 12, 65, 23, 55, 13, 42, 76, 31,
58, 29, 64, 37, 78, 43, 15, 50, 20.

8. The method of claim 7 wherein said encoding step (b) includes a step of including an error-detect code with each message segment arranged to detect errors in the segment.
- 5 9. The method of claim 7 wherein said transmitting step (c) includes a step of including a predetermined test sequence with each packet arranged to determine the channel transmission quality.
- 10 10. The method of claim 7 wherein said encoding step (b) includes a step of including an error-detect code with each message segment arranged to detect errors in the segment, and wherein said transmitting step (c) includes a step of including a predetermined test sequence with each packet arranged to determine the channel transmission quality.

11. In a transmitter arranged for communicating with a receiver via a radio link, a method for receiving a message comprising segments 0, 1, 2, . . . , k-1, k, k+1, . . . , and so forth, and wherein the segments have been encoded into a like number of individual packets, the kth packet
5 containing two segments, that is, a version of the present or kth segment and a version of the preceding or (k-1)th segment, so that each individual message segment is encoded two times, in adjacent packets, the method comprising the following steps:
- (a) receiving a sequence of packets on the radio link;
 - 10 (b) decoding each packet into its two message segment components;
 - (c) after receiving the second version of any given message segment, then selecting the version of that segment that is the highest quality, or lowest error;
 - 15 (d) saving the version of any given message segment thus selected for message reconstruction;
 - (e) repeating steps (a) - (d) for successive packets, thereby reproducing the original message based on message segments 0, 1, 2, 3,
20 . . . , k-1, k, k+1, . . . , and so forth;
 - (f) changing the receive frequency for each packet to be received.

12. The method of claim 11 wherein said changing step (f) includes a
25 step of determining the new frequency for each packet to be received according to an algorithm or "hopping" pattern specially determined to

minimize the probability that any two packets immediately adjacent to one another might be degraded.

13. The method of claim 12 wherein said "hopping" pattern is defined as follows:

- (a) define J frequencies in the hopping sequence;
- (b) arrange the frequencies in a pseudo-random sequence, . . .

5 $f_{(j-1)}, f_j, \dots$, such that $|f_{(j-1)} - f_j| > \Delta f$, where $\Delta f > 5$ MHz.

14. The method of claim 13 wherein the sequence of frequencies, . . . $f_{(j-1)}, f_j, \dots$, is defined as follows:

a set of 83 frequencies identified according to their ascending
10 order, the following list being the order of the sequence:
48, 6, 36, 80, 38, 73, 19, 75, 14, 41, 74, 39, 3, 44, 8, 51, 17, 47, 16,

57, 2, 81, 53, 24, 70, 40, 11, 71, 1, 52, 0, 35, 5, 49, 82, 30, 62, 9, 68, 18,
45, 10, 61, 28, 67, 27, 63, 25,

56, 21, 79, 22, 60, 4, 59, 32, 69, 34, 72, 33, 77, 46, 7, 66, 26, 54, 12, 65,
23, 55, 13, 42, 76, 31, 58, 29, 64,

37, 78, 43, 15, 50, 20.

15. The method of claim 14 wherein said selecting step (c) includes a step of determining segment version quality or error based on an error-
5 detect coded included with each message segment, said error-detect code arranged to detect errors in the segment.
16. The method of claim 14 wherein said selecting step (c) includes a step of determining segment version quality or error based on a
10 predetermined test sequence included with each packet, said test sequence arranged to determine the channel transmission quality.
17. The method of claim 14 wherein said selecting step (c) includes a step of determining segment version quality or error based on an error-
15 detect coded included with each message segment, said error-detect code arranged to detect errors in the segment, and wherein said selecting step (c) further includes a step of determining segment version quality or error based on a predetermined test sequence included with
20 each packet, said test sequence arranged to determine the channel transmission quality.

18. In a personal communication system including a transmitter arranged for communicating with a receiver via a radio frequency link, a method for transmitting and receiving a message comprising the following steps:

5

at said transmitter:

- (a) dividing the message to be sent into segments 0, 1, 2, . . . ,
k-1, k, k+1, . . . , and so forth;
- 10 (b) encoding the message segments into a like number of individual packets, the kth transmitted packet containing two segments, that is, a version of the present or kth segment and a version of the preceding or (k-1)th segment, so that each individual message segment is sent two times, in adjacent packets, and,
- 15 (c) transmitting each packet on the radio link;
- (d) changing the receive frequency for each packet to be sent;

at said receiver:

- 20 (a) receiving the sequence of packets on the radio link,
- (b) decoding each packet into its two message segment components;
- (c) after receiving the second version of any given message segment, then selecting the version of that segment that is the highest
- 25 quality, or lowest error;

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(d) saving the version of any given message segment thus selected for message reconstruction;

(e) repeating steps (a) - (d) for successive packets, thereby reproducing the original message based on message segments 0, 1, 2,
5 3,
..., k-1, k, k+1, ..., and so forth;

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(f) changing the receive frequency for each packet to be received.

19. The method of claim 18 wherein said transmitter changing step (d)
5 and said receiver changing step (f) each include a step of determining the new frequency for each packet to be received according to an algorithm or "hopping" pattern specially determined to minimize the probability that any two packets immediately adjacent to one another might be degraded.

10

20. The method of claim 19 wherein said "hopping" pattern is defined as follows:

(a) define J frequencies in the hopping sequence;

(b) arrange the frequencies in a pseudo-random sequence, . . .

15 $f_{(j-1)}, f_j, \dots$, such that $|f_{(j-1)} - f_j| > \Delta f$, where $\Delta f > 5$ MHz.

21. The method of claim 20 wherein the sequence of frequencies, . . . $f_{(j-1)}, f_j, \dots$, is defined as follows:

a set of 83 frequencies identified according to their ascending
20 order, the following list being the order of the sequence:
48, 6, 36, 80, 38, 73, 19, 75, 14, 41, 74,

39, 3, 44, 8, 51, 17, 47, 16, 57, 2, 81, 53, 24, 70, 40, 11, 71, 1, 52, 0, 35, 5,
49, 82, 30, 62, 9, 68, 18,

45, 10, 61, 28, 67, 27, 63, 25, 56, 21, 79, 22, 60, 4, 59, 32, 69, 34, 72, 33,
77, 46, 7, 66, 26, 54, 12, 65, 23,

55, 13, 42, 76, 31, 58, 29, 64, 37, 78, 43, 15, 50,
20.

22. The method of claim 21 wherein said transmitter encoding step (b)
5 includes a step of including an error-detect code with each message
segment arranged to detect errors in the segment, and said receiver
selecting step (c) includes a step of determining segment version quality
or error based on said error-detect code.
- 10 23. The method of claim 21 wherein said transmitter encoding step (b)
includes a step of including a predetermined test sequence with each
packet arranged to determine the channel transmission quality, and said
receiver selecting step (c) includes a step of determining segment
version quality or error based on said predetermined test sequence.

24. The method of claim 21 wherein:

said transmitter encoding step (b) includes a step of including an error-detect code with each message segment arranged to detect errors in the segment, and a step of including a predetermined test sequence
5 with each packet arranged to determine the channel transmission quality, and

said receiver selecting step (c) includes a step of determining segment version quality or error based on said predetermined test sequence and based on said error-detect code.

AMENDED CLAIMS

[received by the International Bureau on 25 May 1992 (25.05.92
original claims 18-24 cancelled; original claims 1-17
amended; (9 pages)]

- 5 1. In a radio communications system having a transmitter arranged to transmit to a receiver using any one of a plurality of frequencies ("f") in a sequence ... $f_{(j-1)}$, f_j , $f_{(j+1)}$..., a method for the transmitter to send a message to the receiver, the method comprising the steps of:
- 10 (a) dividing the message into a series of N message segments m_1 , m_2 , m_3 , ..., m_N , including a kth message segment m_k ;
- (b) for the kth message segment m_k , where $k = 1, 2, 3, \dots, N$:
- 15 (1) forming a corresponding packet_k based on m_{k-1} and m_k ;
- (2) determining a frequency f_j ;
- (3) transmitting the packet_k on the frequency f_j ;
- (4) repeat (1) through (3) for next j and next k.

2. In a radio communications system having a receiver arranged to receive from a transmitter using any one of a plurality of frequencies ("f") in a sequence . . . $f_{(j-1)}$, f_j , $f_{(j+1)}$, . . . a method for the receiver to receive a message from the transmitter, where the message comprises a series of
- 5 N message segments $m_1, m_2, m_3, \dots, m_N$, the method comprising the steps of:

for $k = 1, 2, 3, \dots, N$:

- (a) determining a frequency f_j ;
- 10 (b) receiving a packet_k on the frequency f_j ;
- (c) forming a first version of received message segment m_{k-1} based on the received packet_{k-1}, and determining a quality or error level of the first version of received message segment m_{k-1} ;
- (d) forming a second version of received message segment m_{k-1}
- 15 based on the received packet_k, and determining a quality or error level of the second version of received message segment m_{k-1} ;
- (e) determining received message segment m_{k-1} based on the first version of received message segment m_{k-1} and the second version of received message segment m_{k-1} , and the quality or error level of the first
- 20 version of received message segment m_{k-1} and the quality or error level of the second version of received message segment m_{k-1} ;
- (f) repeat (a) through (e) for next j and next k;
- (g) form a received message based on received message segments $m_1, m_2, m_3, \dots, m_N$.

3. In a radio communications system having a transmitter arranged to transmit to a receiver using any one of a plurality of frequencies ("f") in a sequence ... $f_{(j-1)}$, f_j , $f_{(j+1)}$..., a method for the transmitter to send a message to the receiver and for the receiver to receive a message from the transmitter, the method comprising the steps of:

at the transmitter:

- (a) dividing the message into a series of N message segments m_1 , m_2 , m_3 , ..., m_N , including a kth message segment m_k ;
- 10 (b) for the kth message segment m_k , where $k = 1, 2, 3, \dots, N$:
- (1) forming a corresponding packet_k based on m_{k-1} and m_k ;
- (2) determining a frequency f_j ;
- (3) transmitting the packet_k on the frequency_j;
- (4) repeat (1) through (3) for next j and next k;

15

at the receiver, for $k = 1, 2, 3, \dots, N$:

- (a) determining a frequency f_j ;
- (b) receiving a packet_k on the frequency f_j ;
- (c) forming a first version of received message segment m_{k-1} based on the received packet_{k-1}, and determining a quality or error level of the first version of received message segment m_{k-1} ;
- 20 (d) forming a second version of received message segment m_{k-1} based on the received packet_k, and determining a quality or error level of the second version of received message segment m_{k-1} ;
- 25 (e) determining received message segment m_{k-1} based on the first version of received message segment m_{k-1} and the second version of received message segment m_{k-1} , and the quality or error level of the first version of received message segment m_{k-1} and the quality or error level of the second version of received message segment m_{k-1} ;
- 30 (f) repeat (a) through (e) for next j and next k;
- (g) form a received message based on received message segments $m_1, m_2, m_3, \dots, m_N$.

4. In a transmitter arranged for communicating with a receiver via a radio frequency link, the radio frequency link having a plurality of transmit frequencies, the radio frequency link having a channel transmit quality, a method for transmitting a message comprising the following steps:

5 (a) dividing the message to be sent into message segments 0, 1, 2, ..., k-1, k, k+1, ..., N, including a kth message segment and a (k-1)th message segment;

(b) encoding the message segments into a like number of individual packets, including a kth packet, the kth packet containing two message segments, that is, a version of the kth message segment and a version of the (k-1)th message segment, so that each individual message segment is sent two times, in adjacent packets, and,

10 (c) transmitting each packet on the radio link;

(d) changing the transmit frequency for each packet to be sent.

15

5. The method of claim 4, wherein there exists a probability that any two packets immediately adjacent to one another might be degraded, and wherein said changing step (d) includes a step of determining the new frequency for each packet to be sent according to an algorithm comprising a "hopping" pattern specially determined to minimize the probability that any two packets immediately adjacent to one another might be degraded.

20

6. The method of claim 5 wherein said "hopping" pattern is defined as follows:

25

(a) define J frequencies in the hopping pattern;

(b) arrange the frequencies in a pseudo-random sequence of frequencies, ... $f_{(j-1)}$, f_j , ... , such that $|f_{(j-1)} - f_j| > \Delta f$, where $\Delta f > 5$ MHz.

7. The method of claim 6 wherein the pseudo-random sequence of frequencies, . . . $f_{(j-1)}$, f_j , . . . , is defined as follows:

a set of 83 frequencies identified according to their ascending order, the following list being the order of the sequence: 48, 6, 36, 80,
5 38, 73, 19, 75, 14, 41, 74, 39, 3, 44, 8, 51, 17, 47, 16, 57, 2, 81, 53, 24, 70,
40, 11, 71, 1, 52, 0, 35, 5, 49, 82, 30, 62, 9, 68, 18, 45, 10, 61, 28, 67, 27,
63, 25, 56, 21, 79, 22, 60, 4,
59, 32, 69, 34, 72, 33, 77, 46, 7, 66, 26, 54, 12, 65, 23, 55, 13, 42, 76, 31,
58, 29, 64, 37, 78, 43, 15, 50, 20.

8. The method of claim 7 wherein said encoding step (b) includes a step of including an error-detect code with each message segment, the error-detect code arranged to detect errors in the message segment.
- 5 9. The method of claim 7 wherein said transmitting step (c) includes a step of including a predetermined test sequence with each packet, the predetermined test sequence arranged to determine the channel transmission quality.
- 10 10. The method of claim 7 wherein said encoding step (b) includes a step of including an error-detect code with each message segment, the error-detect code arranged to detect errors in the message segment, and wherein said transmitting step (c) includes a step of including a
- 15 sequence arranged to determine the channel transmission quality.

11. In a receiver arranged for communicating with a transmitter via a radio link, the radio link having a plurality of receive frequencies, the radio link having a channel reception quality, a method for receiving a message comprising message segments 0, 1, 2, . . . , k-1, k, k+1, . . . , N, and wherein the message segments have been encoded into a like number of individual packets, the kth packet containing two message segments, that is, a version of the kth message segment and a version of the (k-1)th message segment, so that each individual message segment is encoded two times, including a first version and a second version, in adjacent packets, and where each received message segment contains a finite quality or error such that, when the first version and second version of any given message segment are received, it is possible to determine which version contains the highest quality or lowest error, the method comprising the following steps:
- (a) receiving a sequence of packets on the radio link;
 - (b) decoding each packet into its two message segment components;
 - (c) after receiving the second version of any given message segment, then selecting the version of that message segment that is the highest quality, or lowest error;
 - (d) saving the version of any given message segment thus selected for message reconstruction;
 - (e) repeating steps (a) - (d) for successive packets, thereby reproducing the original message based on message segments 0, 1, 2, 3, . . . , k-1, k, k+1, . . . , N;
 - (f) changing the receive frequency for each packet to be received.
12. The method of claim 11 wherein said changing step (f) includes a step of determining the new frequency for each packet to be received according to an algorithm comprising a "hopping" pattern specially determined to minimize the probability that any two packets immediately adjacent to one another might be degraded.

13. The method of claim 12 wherein said "hopping" pattern is defined as follows:

- (a) define J frequencies in the hopping pattern;
- (b) arrange the frequencies in a pseudo-random sequence of
5 frequencies, $\dots f_{(j-1)}, f_j, \dots$, such that $|f_{(j-1)} - f_j| > \Delta f$, where $\Delta f > 5$ MHz.

14. The method of claim 13 wherein the pseudo-random sequence of frequencies, $\dots f_{(j-1)}, f_j, \dots$, is defined as follows:

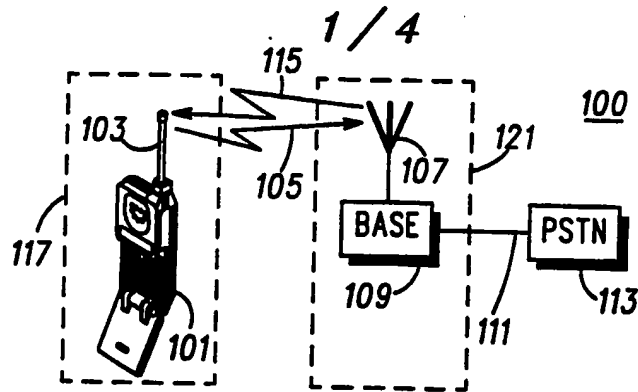
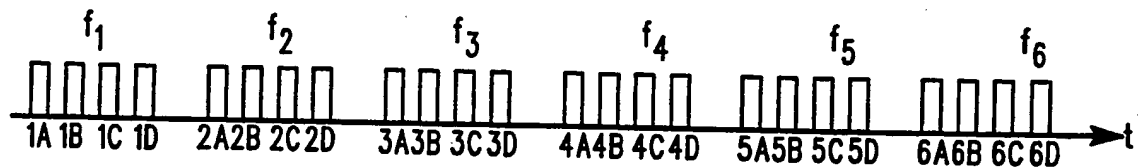
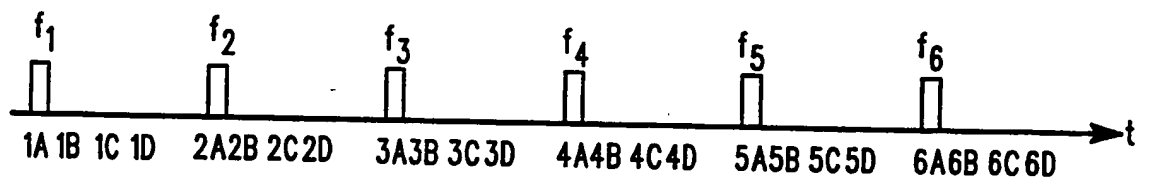
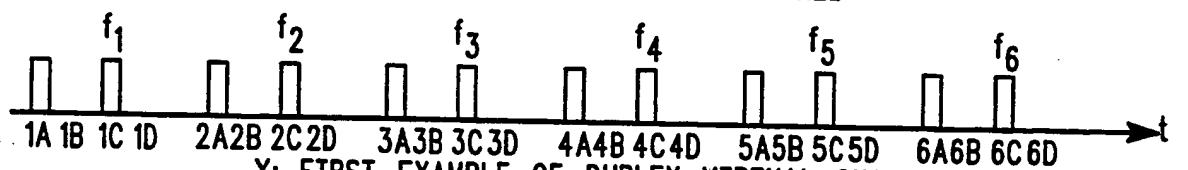
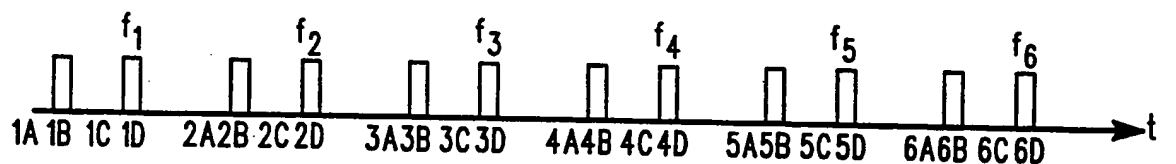
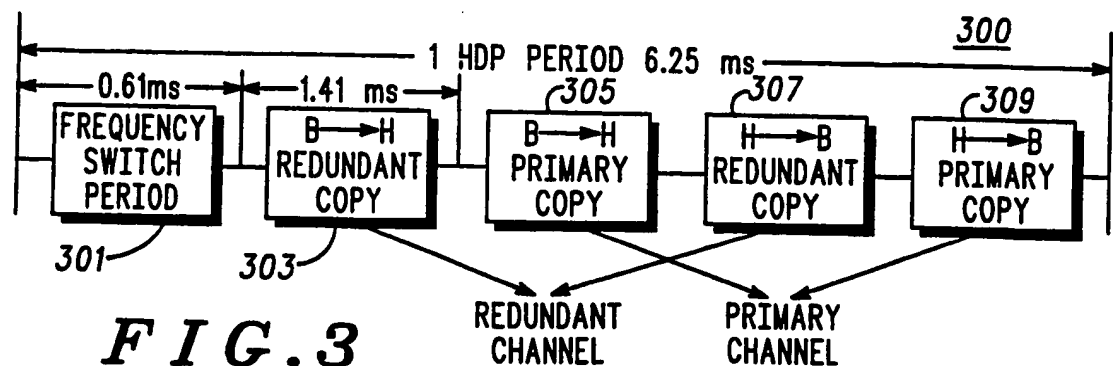
- 10 a set of 83 frequencies identified according to their ascending order, the following list being the order of the sequence: 48, 6, 36, 80, 38, 73, 19, 75, 14, 41, 74, 39, 3, 44, 8, 51, 17, 47, 16, 57, 2, 81, 53, 24, 70, 40, 11, 71, 1, 52, 0, 35, 5, 49, 82, 30, 62, 9, 68, 18, 45, 10, 61, 28, 67, 27, 63, 25, 56, 21, 79, 22, 60, 4, 59, 32, 69, 34, 72, 33, 77, 46, 7, 66, 26, 54, 12, 65, 23, 55, 13, 42, 76, 31, 58, 29, 64,

37, 78, 43, 15, 50, 20.

15. The method of claim 14 wherein said selecting step (c) includes a step of determining message segment version quality or error based on an error-detect code, the error-detect code included with each message segment, said error-detect code arranged to detect errors in the message segment.

16. The method of claim 14 wherein said selecting step (c) includes a step of determining message segment version quality or error based on a predetermined test sequence, the predetermined test sequence included with each packet, said predetermined test sequence arranged to determine the channel reception quality.

17. The method of claim 14 wherein said selecting step (c) includes a step of determining message segment version quality or error based on an error-detect code, the error-detect code being included with each message segment, said error-detect code arranged to detect errors in the message segment, and wherein said selecting step (c) further includes a step of determining message segment version quality or error based on a predetermined test sequence, the predetermined test sequence being included with each packet, said predetermined test sequence arranged to determine the channel reception quality.

**FIG. 1-****W: EXAMPLE OF FREQUENCY HOP FORWARD****X: EXAMPLE OF VIRTUAL CHANNEL****Y: FIRST EXAMPLE OF DUPLEX VIRTUAL CHANNEL****Z: SECOND EXAMPLE OF DUPLEX VIRTUAL CHANNEL****FIG. 2****FIG. 3**

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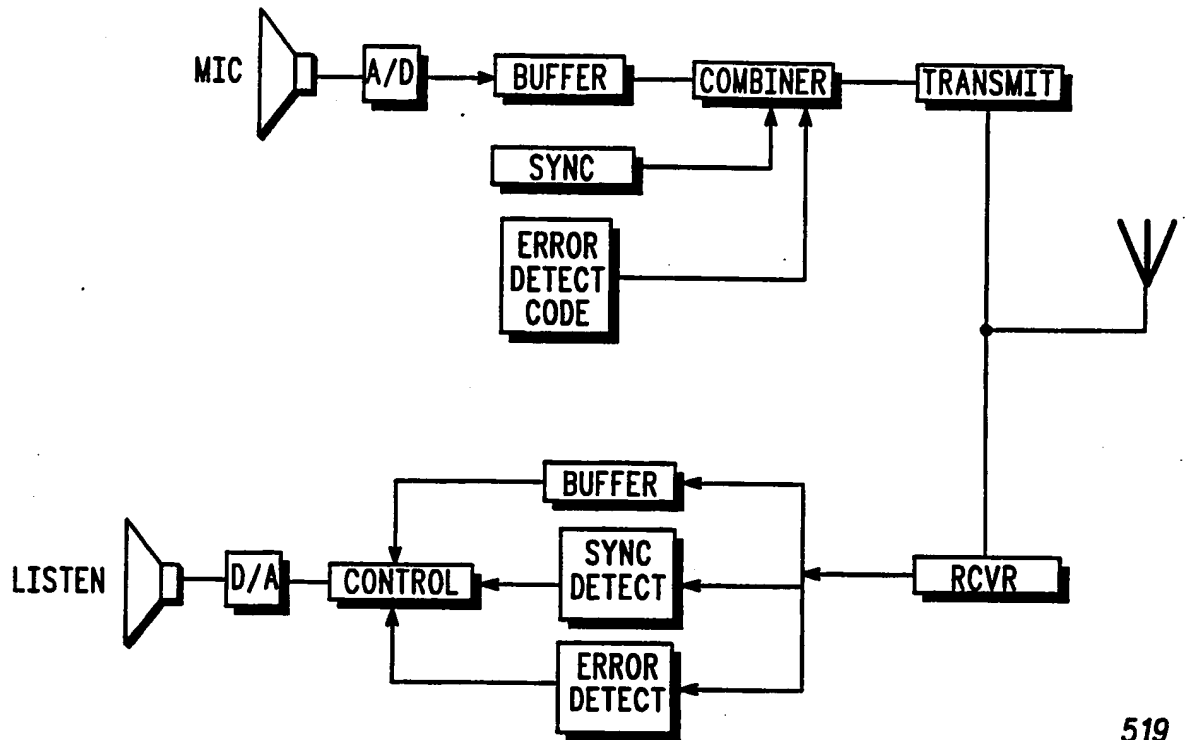


FIG. 4

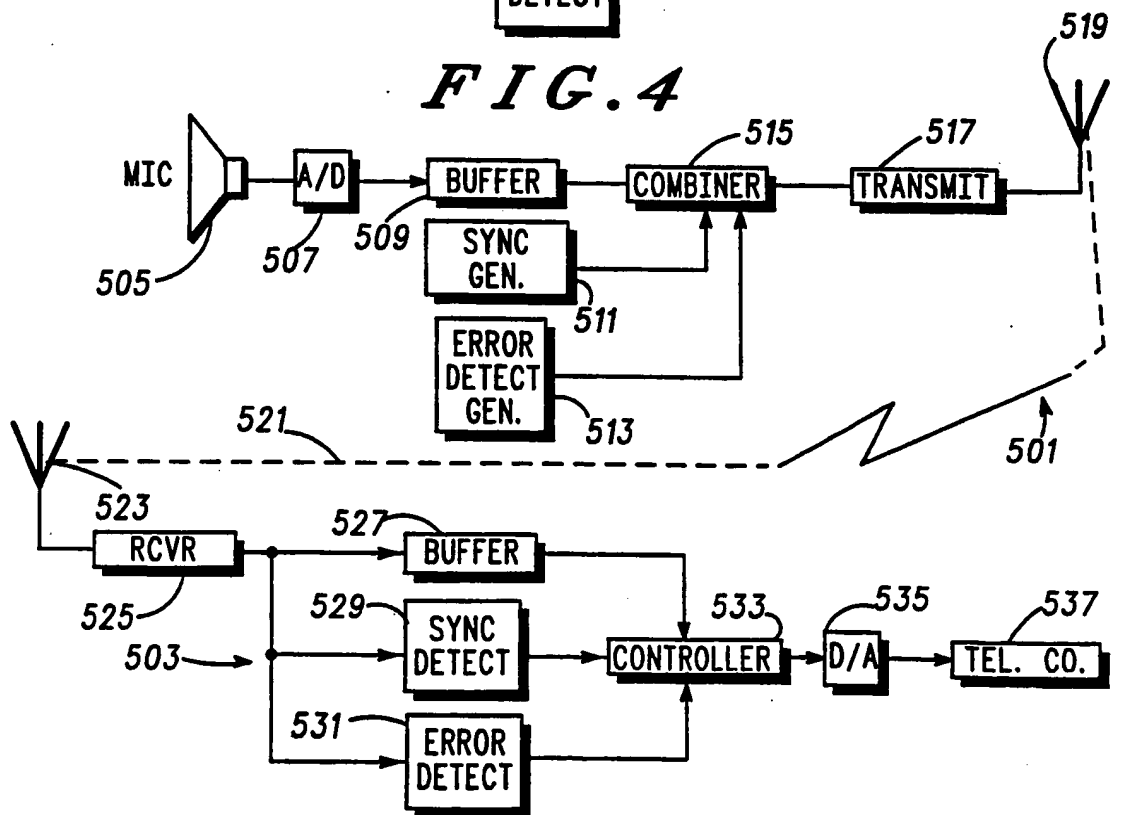


FIG. 5

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		TRUTH TABLE			
PARITY CODE		COPY 1	CORRECT	CORRECT	INCORR INCORR
		COPY 2	CORRECT	INCORR	CORRECT INCORR
		COPY 1	COPY 2		
SYNC WORD	CORRECT	CORRECT	COPY 1	COPY 1	COPY 2 COPY 1
	CORRECT	INCORR	COPY 1	COPY 1	COPY 2 COPY 1
	INCORR	CORRECT	COPY 1	COPY 1	COPY 2 COPY 2
	INCORR	INCORR	COPY 1	COPY 1	COPY 2 MUTE

FIG. 6

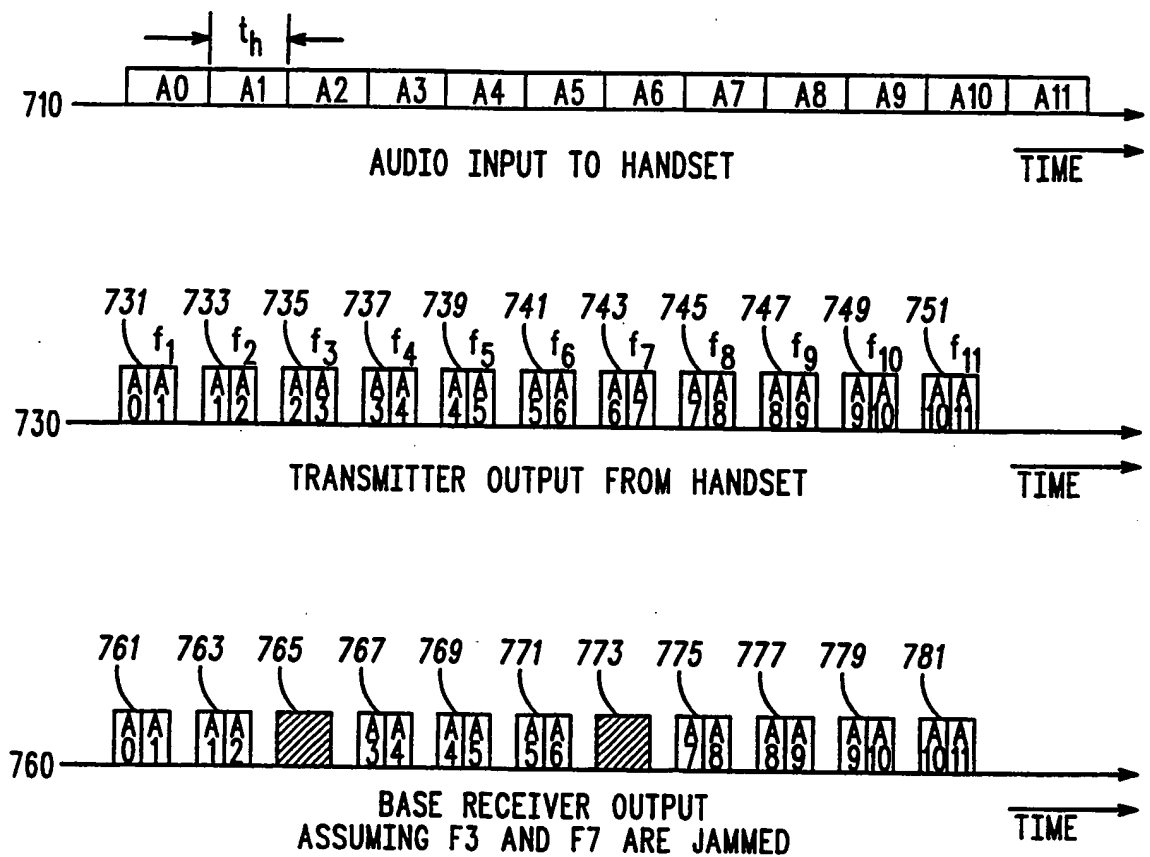
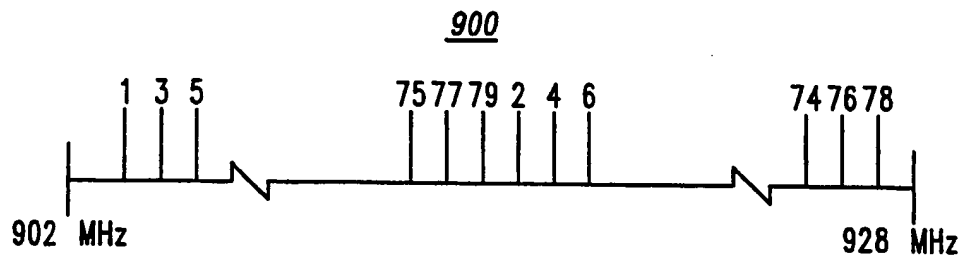
RECEIVED STATUS OF AUDIO BLOCKS

AUDIO BLOCK	FIRST COPY	SECOND COPY	COPY USED FOR OUTPUT
A1	REC'D ON F0	REC'D ON F1	FIRST
A2	REC'D ON F1	REC'D ON F2	FIRST
A3	REC'D ON F2	NOT REC'D F3	FIRST
A4	NO REC'D ON F3	REC'D ON F4	SECOND
A5	REC'D ON F4	REC'D ON F5	FIRST
A6	REC'D ON F5	REC'D ON F6	FIRST
A7	REC'D ON F6	NOT REC'D ON F7	FIRST
A8	NOT REC'D ON F7	REC'D ON F8	SECOND
A9	REC'D ON F8	REC'D ON F9	FIRST
A10	REC'D ON F9	REC'D ON F10	FIRST

FIG. 8

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**FIG. 7****FIG. 9**

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US91/09803

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): G06F 11/10

U.S.Cl.: 371/69.1

II. FIELDS SEARCHED

Minimum Documentation Searched ⁷

Classification System

Classification Symbols

U.S.Cl.

371/2.1,20.1,38.1,39.1,49.1,69.1; 375/1,40,48,89,100,104;
455/63,73

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched ⁸

III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹

Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X Y	James McDonald, "Digital Cordless Telecommunications System", 08 December 1989, Motorola, Inc., Schaumburg, IL pp. 037-057.	1-5,8-12, 15-19,22-24 6,7,13,14,20, 21
A	US, A, 4,606,041 (KADIN) 12 August 1986 (See abstract).	1-24
A	US, A, 4,759,022 (AKERBERG) 19 July 1988 (See figure 1).	1-24
A	US, A, 4,852,105 (KURZ) 25 July 1989 (See figure 1).	1-24
A	US, A, 4,908,828 (TIKALSKY) 13 March 1990 (See abstract).	1-24
A,P	US, A, 5,022,029 (GUICHON) 04 June 1991 (See figure 6).	1-24

¹⁰ Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

05 February 1992

International Searching Authority

ISA/US

Date of Mailing of this International Search Report

23 MAR 1992

Signature of Authorized Officer

Robert Beausoliel
Robert Beausoliel